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(54) **BUILT-IN ANTENNA APPARATUS**

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(52) **U.S. Cl.** **343/818**; 343/702; 343/795
(58) **Field of Search** .... 343/700 MS, 702, 343/795, 803, 806, 810, 815, 817, 818

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,812,855 A	*	3/1989	Coe et al.	343/818
6,046,703 A		4/2000	Wang et al.	343/795
6,281,843 B1	*	8/2001	Evtioushkine et al.	343/700 MS
6,326,922 B1	*	12/2001	Hegendoerfer	343/700 MS

FOREIGN PATENT DOCUMENTS

EP	1111718	6/2001
EP	1154513	11/2001
JP	61205004	9/1986
JP	08335818	12/1996
JP	11274845	10/1999
JP	2000004120	1/2000
JP	2000349526	12/2000
JP	2001077611	3/2001
JP	2001085920	3/2001
JP	2002151923	5/2002
WO	0148860	7/2001

OTHER PUBLICATIONS

International Search Report dated Sep. 10, 2002.

* cited by examiner

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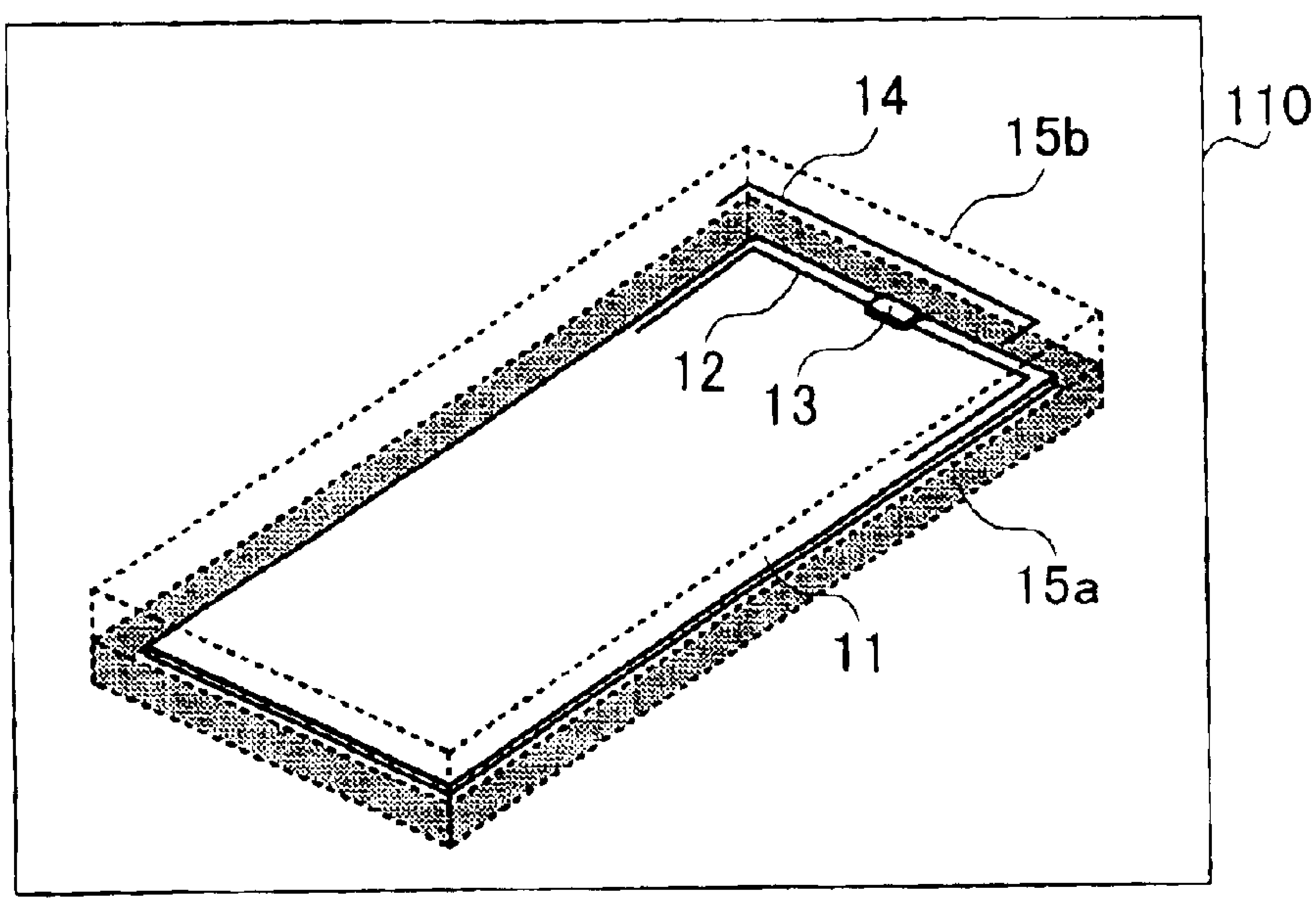
(57) **ABSTRACT**

A built-in antenna device that broadens bandwidth and that realizes further miniaturization and thin-modeling without making a device itself a flat shape, while still enhancing gain and reducing SAR (specific Absorption Rate). The self impedance of dipole antenna **12**, the self impedance of parasitic element **14**, and the mutual impedance between dipole antenna **12** and parasitic element **14** change as the length and girth of dipole antenna **12** and parasitic element **14**, and the distance therebetween are adjusted to predetermined levels, so as to broaden bandwidth by changing the input impedance of built-in antenna **10**.

26 Claims, 6 Drawing Sheets



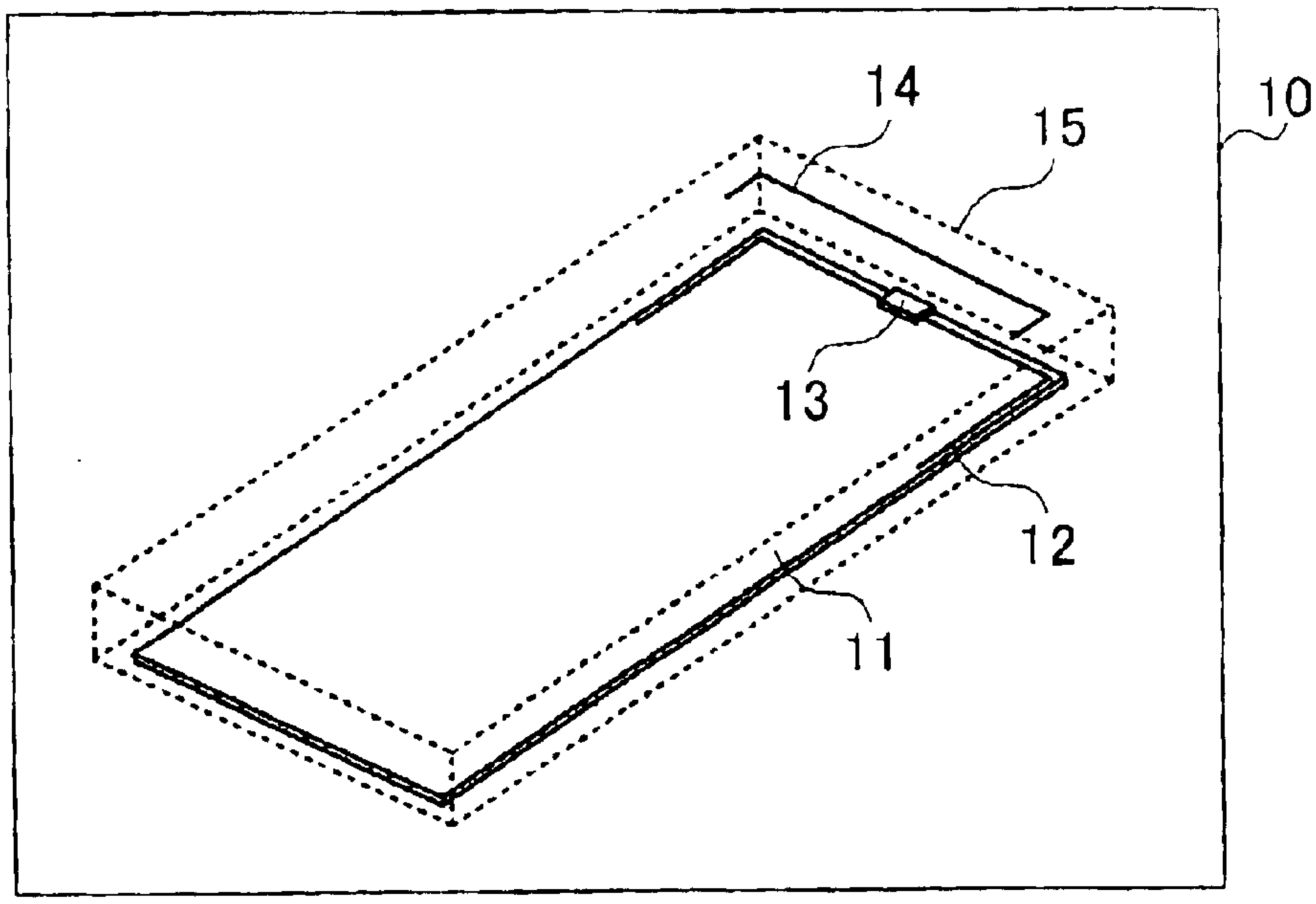


FIG.1

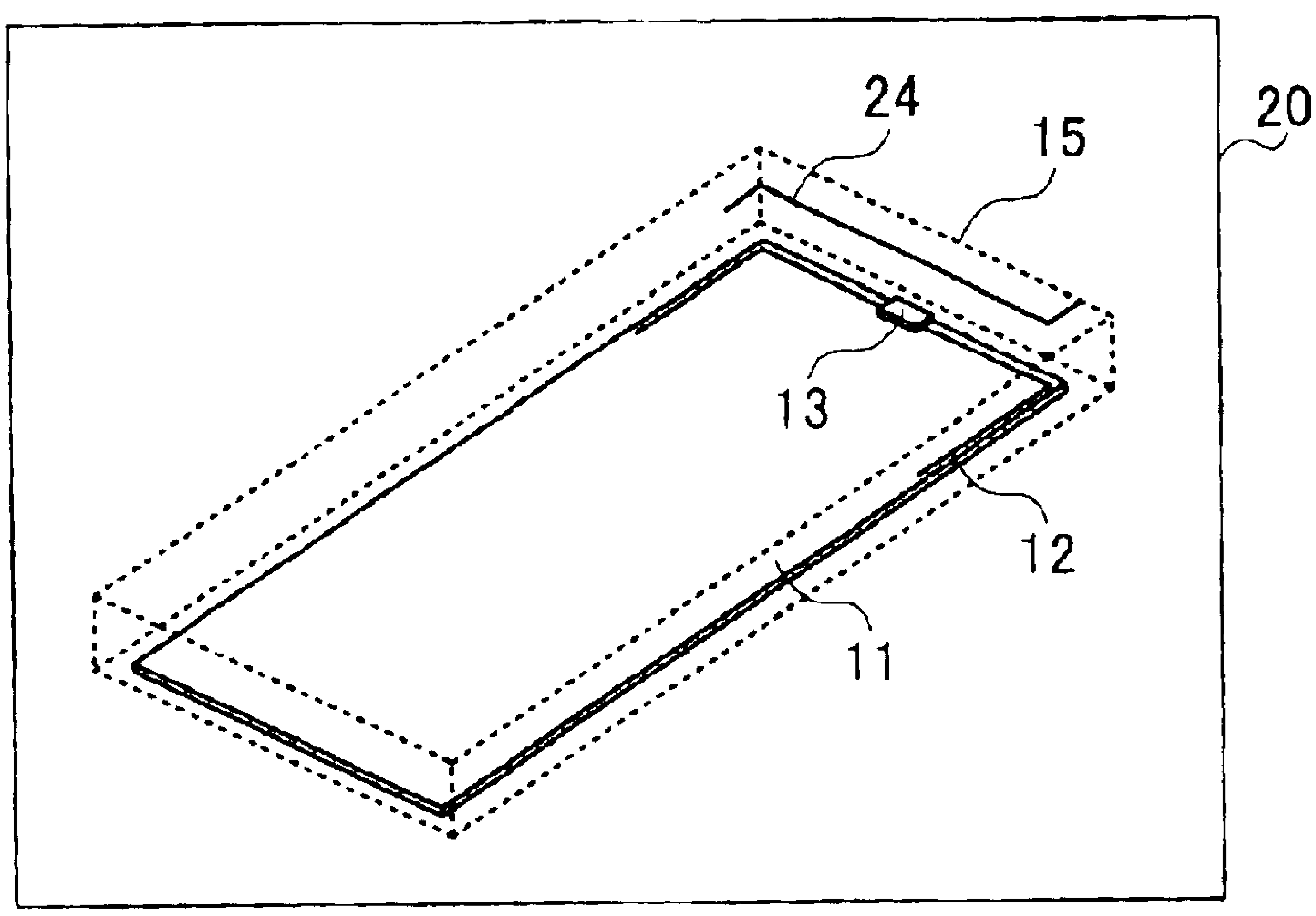


FIG.2

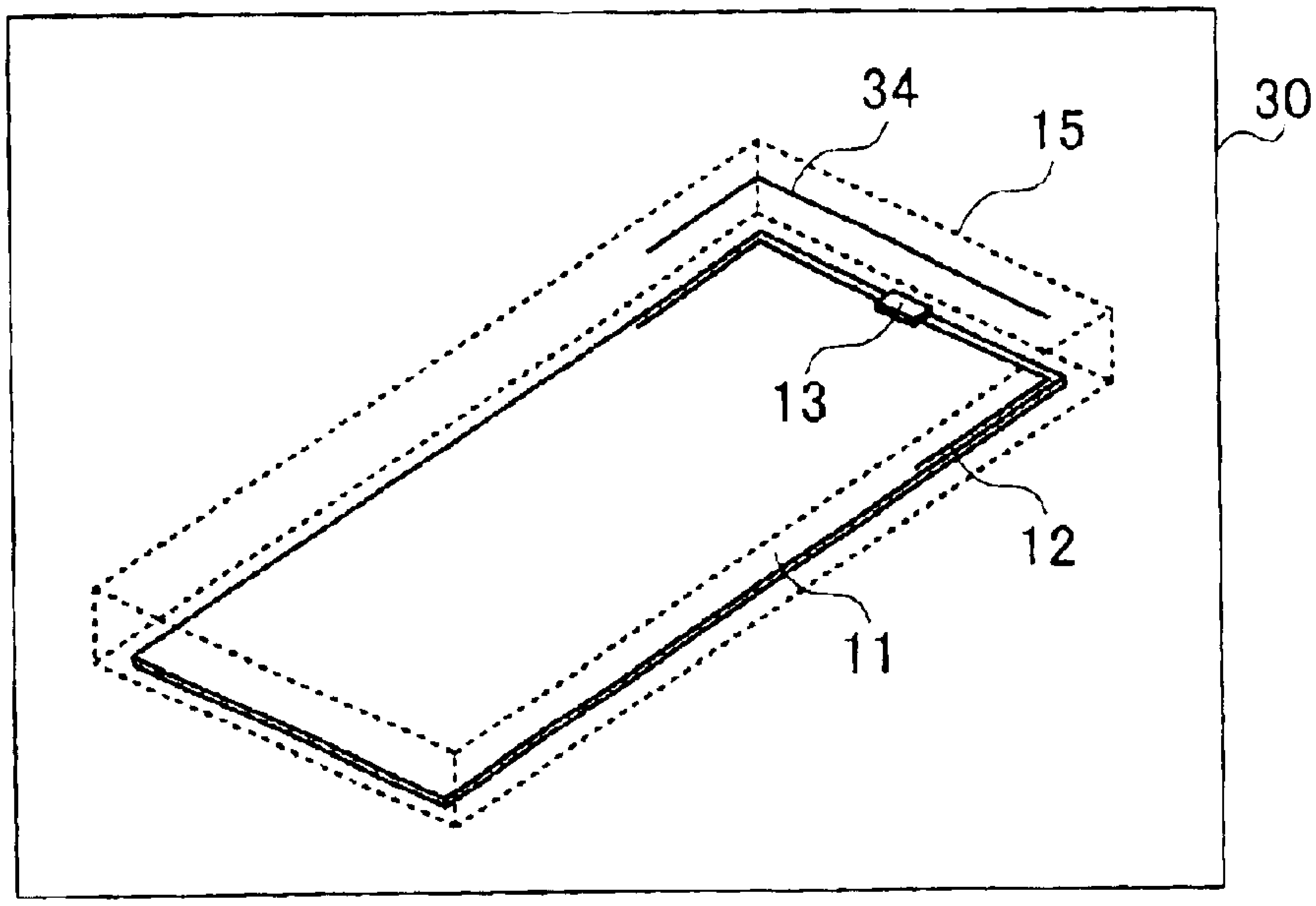


FIG.3

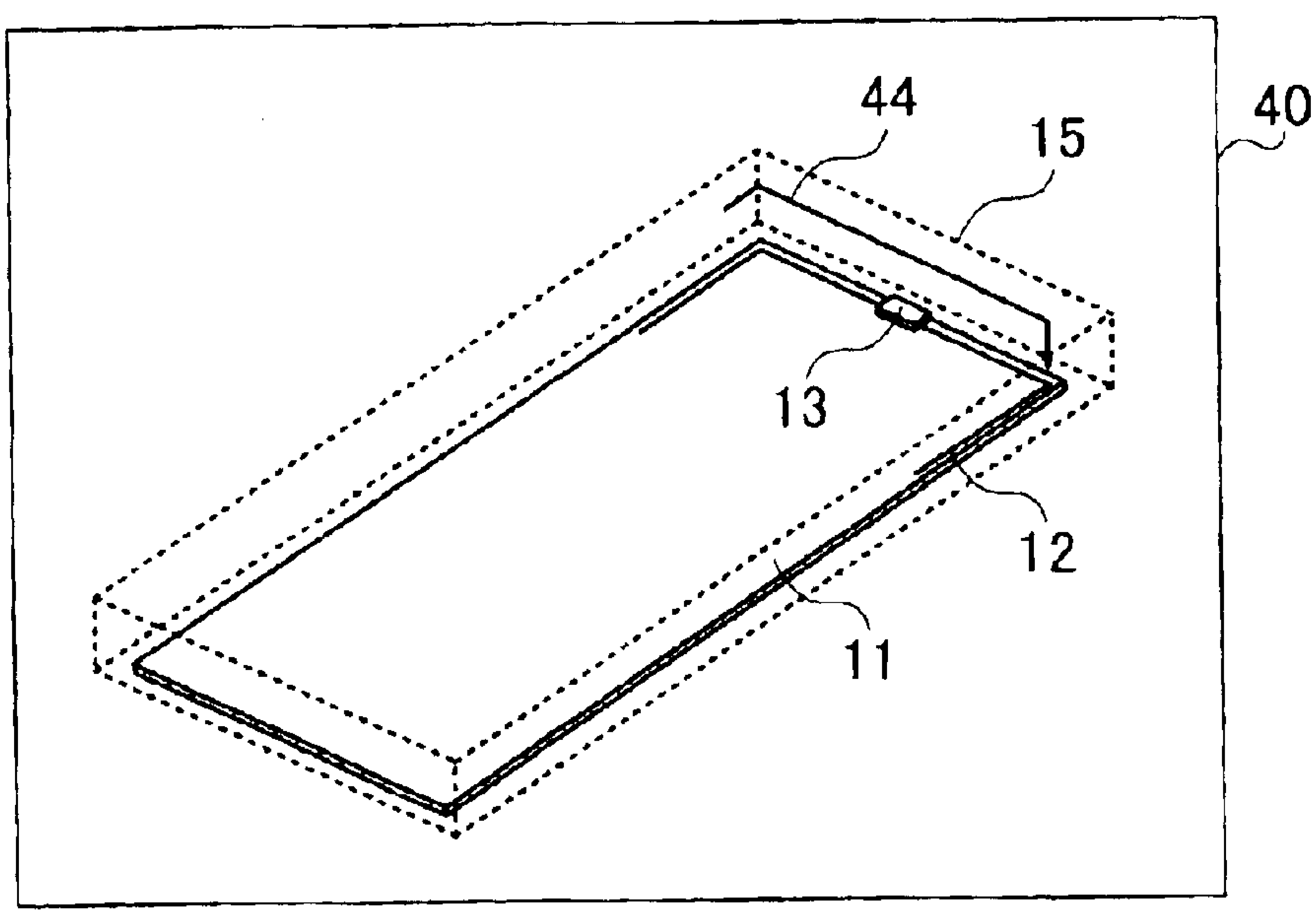


FIG.4

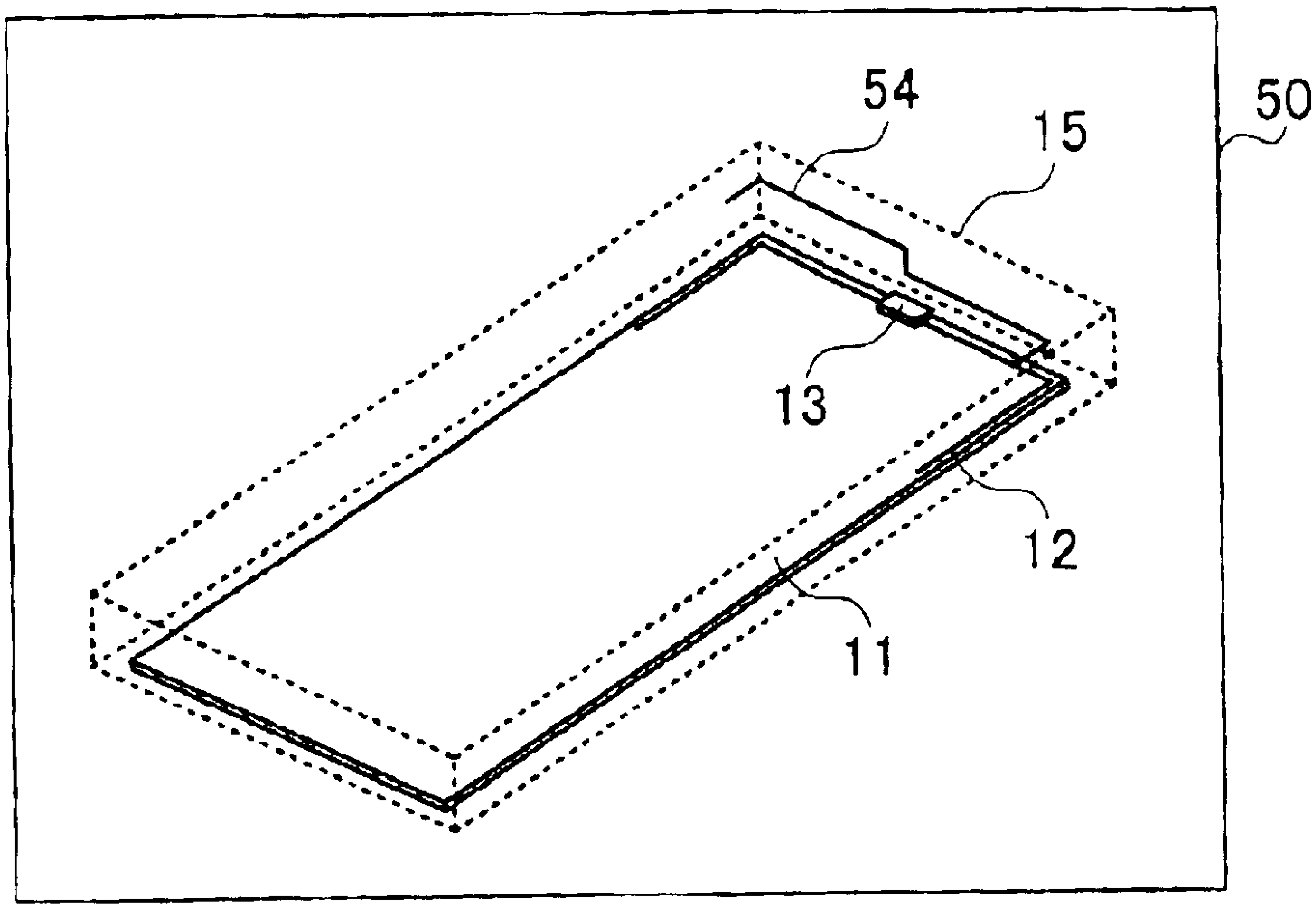


FIG.5

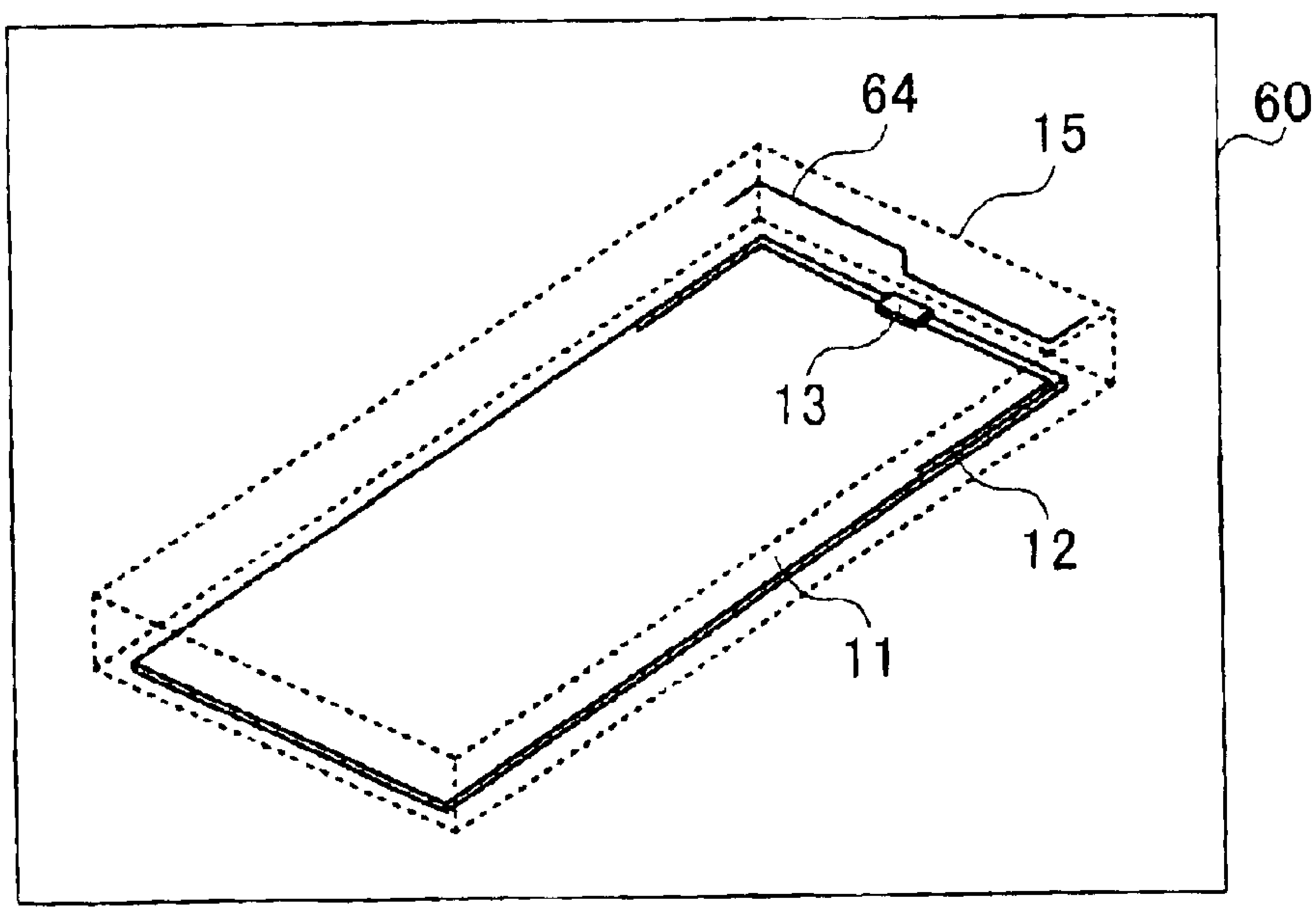


FIG.6

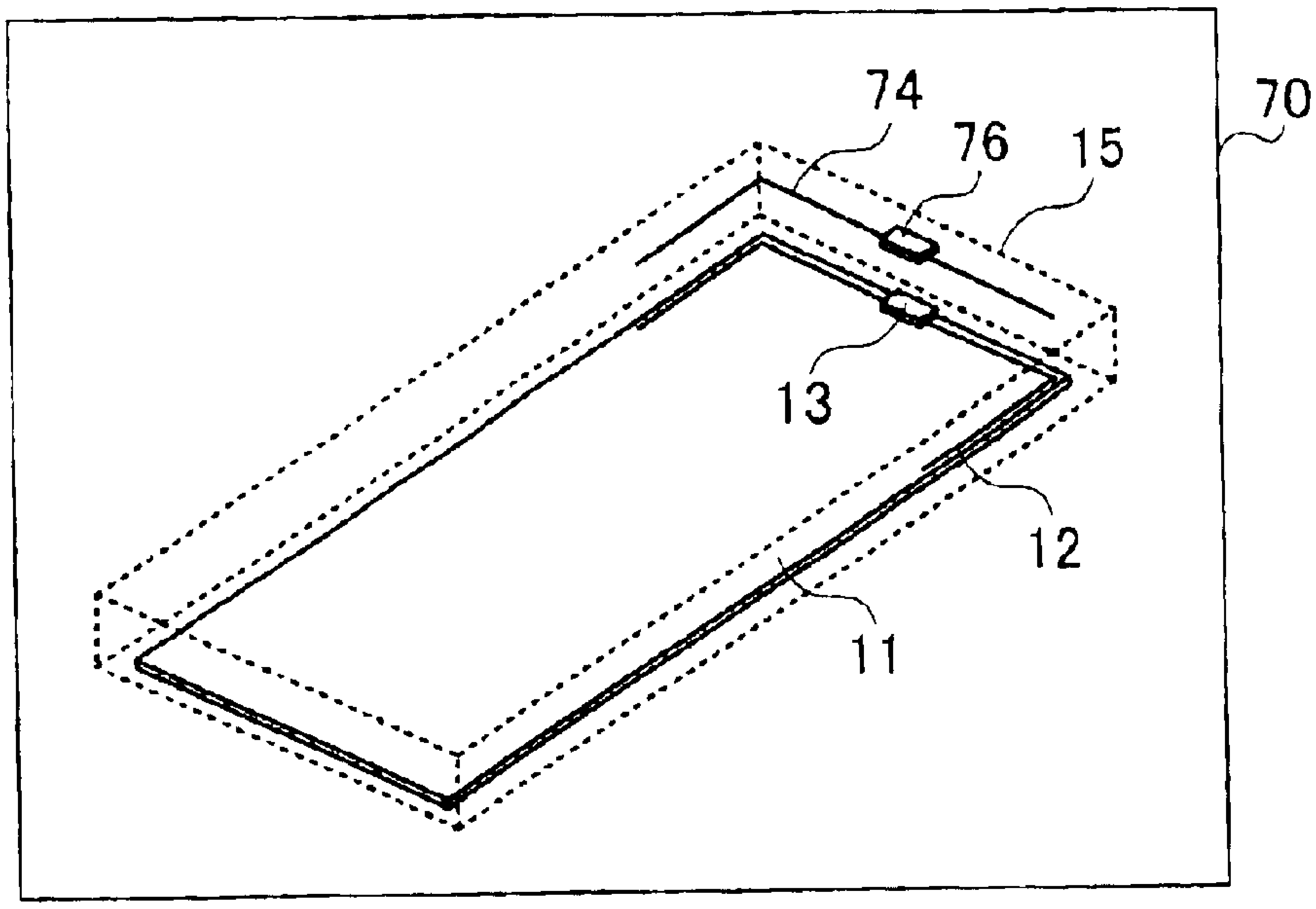


FIG.7

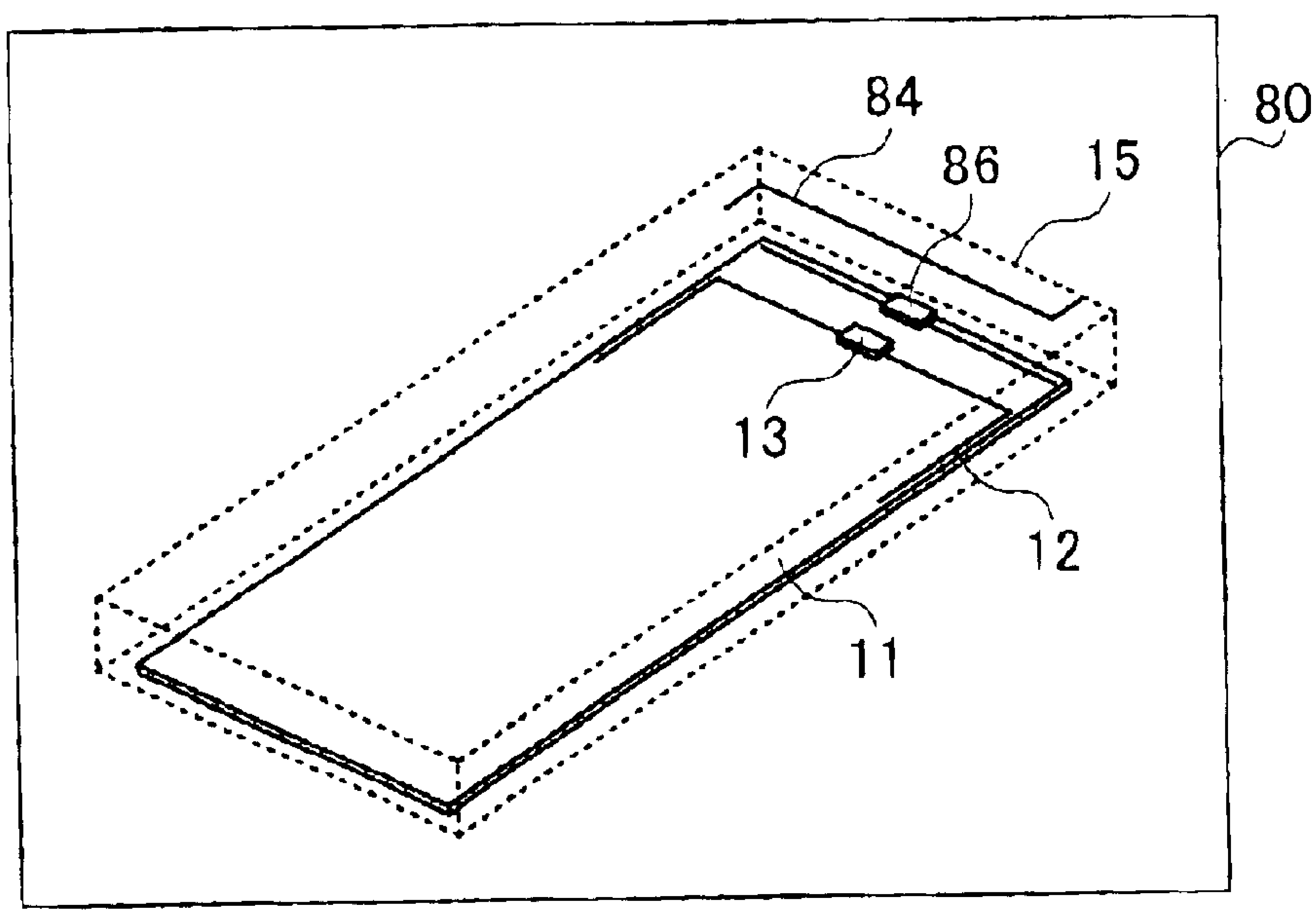


FIG.8

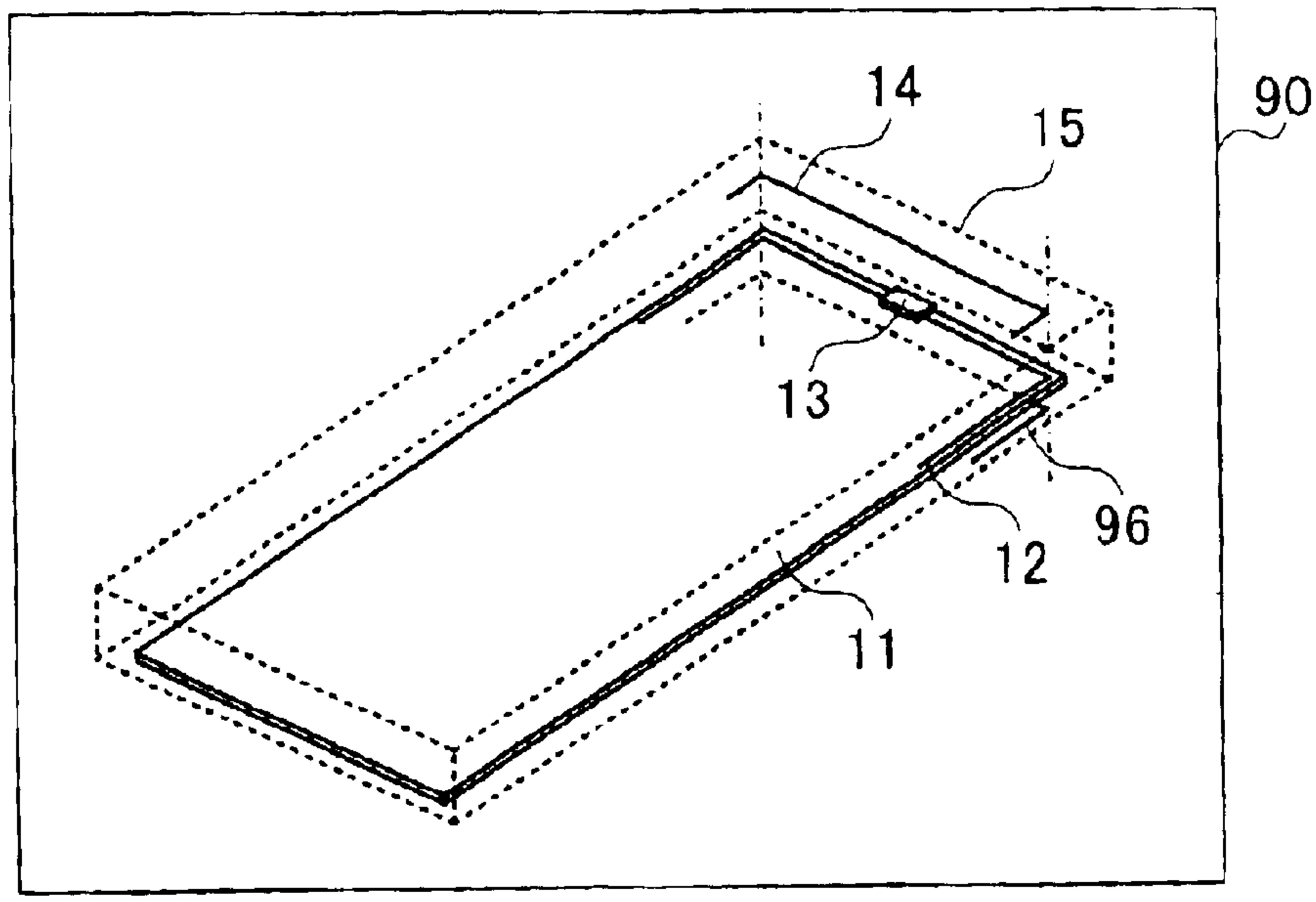


FIG.9

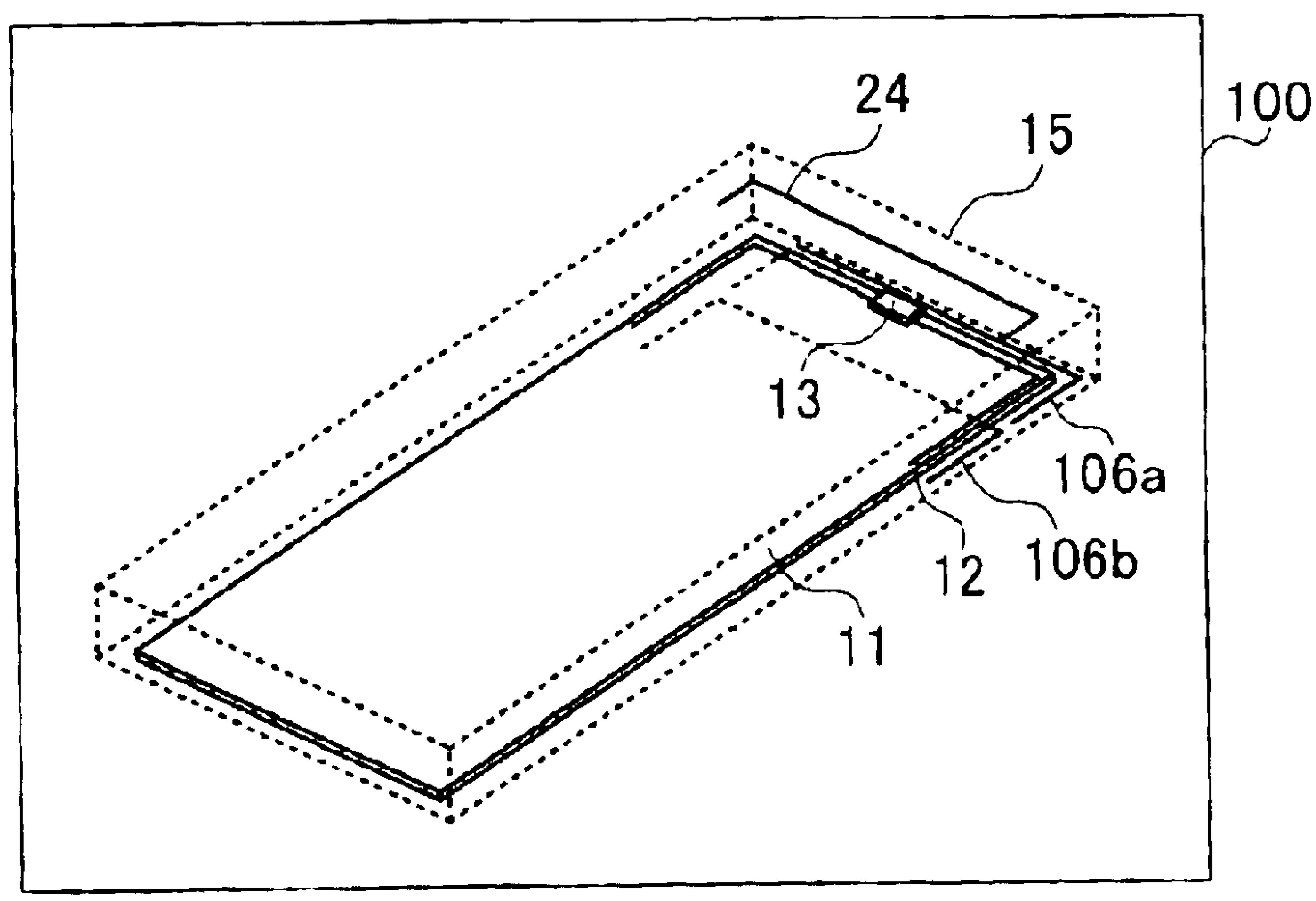


FIG.10

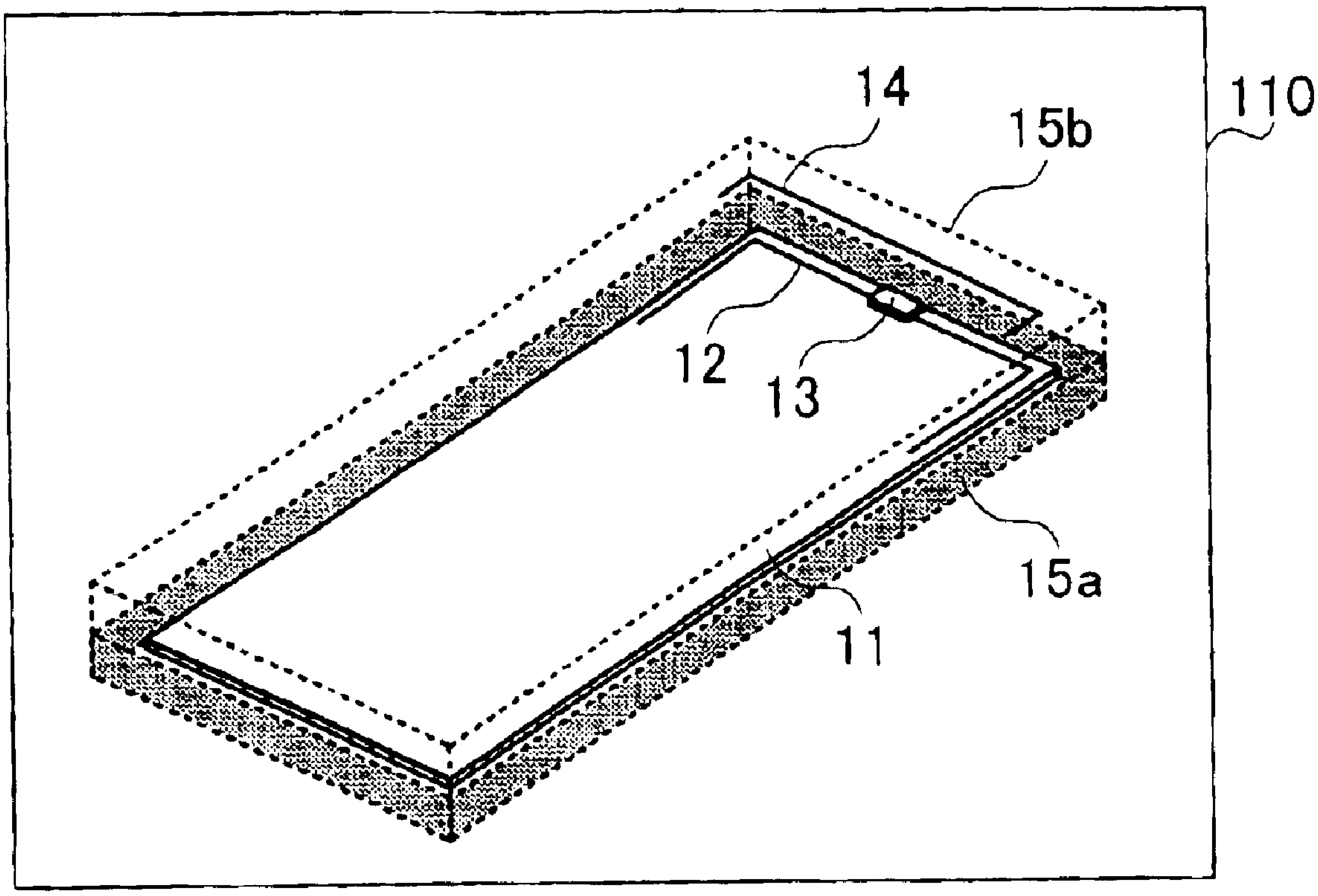


FIG.11

BUILT-IN ANTENNA APPARATUS

TECHNICAL FIELD

The present invention relates to built-in antennas.

BACKGROUND ART

In recent years, communication devices such as mobile terminal devices have steadily spread, and there has been a demand for miniaturization of communication devices. There has also been a demand for miniaturization and thin-modeling of built-in antenna devices that are built in these communication devices.

These built-in antenna devices should be able to operate at a wide bandwidth, within the bandwidth that is required by the mobile communication systems in which communications terminals such as mobile terminal devices are used.

Japanese laid-open patent publication No. 2000-349526 discloses an example of built-in antenna device of the above type. This built-in antenna aims to broaden bandwidth and, at the same time, aims at miniaturization and thin-modeling, by configuring an elongated antenna element into a continuous surface of a zigzag shape and such, without excessively shortening the length of its central axis length (antenna length), or by providing electro-magnetic wave absorbing material of a certain width near the antenna element.

Nevertheless, with a typical built-in antenna device, an antenna element has a continuous surface, or, a built-in antenna itself has a flat shape to have electro-magnetic wave absorbing material of a certain width provided, and thus a certain width is required and miniaturization and thin-modeling are limited.

Furthermore, an antenna needs to operate at a wide bandwidth and enhance gain during communication to utilize the frequency band used by a system, and yet a single antenna element can enhance gain only to a limited extent.

DISCLOSURE OF INVENTION

The present invention is therefore directed to broadening bandwidth, and realizing further miniaturization and thin modeling without making the whole device in a flat shape.

In addition to the miniaturization and thin modeling that does not require making the whole device a flat shape, the present invention is directed to enhancing gain and reducing SAR (Specific Absorption Rate).

The essence of the present invention is to broaden bandwidth and to make a built-in antenna device small and thin, by positioning a power-supplied radiation element and a parasitic element for use in matching in opposition to each other, and without making the radiation element a flat shape such as a thick board shape.

One aspect of the invention presented herein is a built-in antenna device comprising: a radiation element of a dipole configuration that is supplied power and provided on a circuit board, both ends of the radiation element turned in a same direction; a parasitic element for use in matching provided opposite to the radiation element, both ends of said parasitic element bent to the same direction as the both ends of the radiation element; and a case current suppressor provided in a power supply part of the radiation element to suppress a case current.

Another aspect of the invention presented herein is a built-in antenna device comprising: a radiation element of a dipole configuration that is supplied power and provided on a circuit board, both ends of the radiation element turned in a same direction; a parasitic element for use in matching provided opposite to the radiation element, one end of said parasitic element bent to the same direction as the both ends of the radiation element, and the other end bent to an opposite direction; and a case current suppressor provided in a power supply part of the radiation element to suppress a case current.

Yet another aspect of the invention presented herein is a built-in antenna device comprising: a radiation element of a dipole configuration that is supplied power and provided on a circuit board, both ends of the radiation element turned in a same direction; a parasitic element for use in matching provided opposite to the radiation element, only one end of the parasitic element bent to the same direction as the both ends of the radiation element; and a case current suppressor provided in a power supply part of the radiation element to suppress a case current.

Yet another aspect of the invention presented herein is a built-in antenna device comprising: a radiation element of a dipole configuration that is supplied power and provided on a circuit board, both ends of the radiation element turned in a same direction; a parasitic element for use in matching provided opposite to the radiation element, one end of the parasitic element bent to the same direction as the both ends of the radiation element, and the other end bent to a direction that is perpendicular to a plane of the circuit board; and a case current suppressor provided in a power supply part of the radiation element to suppress a case current.

Yet another aspect of the invention presented herein is a built-in antenna device comprising: a radiation element of a dipole configuration that is supplied power and provided on a circuit board, both ends of the radiation element turned in a same direction; a parasitic element for use in matching provided near the radiation element on the circuit board; and a case current suppressor provided in a power supply part of the radiation element to suppress a case current.

Yet another aspect of the invention presented herein is a built-in antenna device comprising: a radiation element of a dipole configuration that is supplied power and provided on a circuit board, both ends of the element turned in a same direction; a case, at least a portion of which that is opposite to the radiation element over the circuit board is made of steel; and a case current suppressor provided in a power supply part of the radiation element to suppress a case current.

Yet another aspect of the invention presented herein is a built-in antenna device comprising: a radiation element of a dipole configuration that is supplied power and provided on a circuit board, both ends of the radiation element turned in mutually opposite directions; a case, at least a portion oh which that is opposite to the radiation element over the circuit board is made of steel; and a case current suppressor provided in a power supply part of the radiation element to suppress a case current.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** shows a configuration of a built-in antenna device according to the first embodiment of the present invention;

FIG. **2** shows a configuration of a built-in antenna device according to the second embodiment of the present invention;

FIG. **3** shows a configuration of a built-in antenna device according to the third embodiment of the present invention;

FIG. **4** shows a configuration of a built-in antenna device according to the fourth embodiment of the present invention;

FIG. **5** shows a configuration of a built-in antenna device according to the fifth embodiment of the present invention;

FIG. **6** shows a configuration of a built-in antenna device according to the sixth embodiment of the present invention;

FIG. **7** shows a configuration of a built-in antenna device according to the seventh embodiment of the present invention;

FIG. **8** shows a configuration of a built-in antenna device according to the eighth embodiment of the present invention;

FIG. **9** shows a configuration of a built-in antenna device according to the ninth embodiment of the present invention;

FIG. **10** shows a configuration of a built-in antenna device according to the tenth embodiment of the present invention; and

FIG. **11** shows a configuration of a built-in antenna device according to the eleventh embodiment of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

With reference to the accompanying drawings now, preferred embodiments of the present invention will be described below.

First Embodiment

FIG. **1** shows a configuration of a built-in antenna device according to the first embodiment of the present invention.

Built-in antenna device **10** comprises circuit board **11**, dipole antenna (radiation element) **12**, balun **13**, parasitic element **14**, and case **15**. Hereinafter the length direction of case **15** shall be construed such that the direction where dipole antenna **12**, balun **13**, and parasitic element **14** lie is the depth side, and the direction where dipole antenna **12**, balun **13**, and parasitic element **14** are not provided is the front side.

Dipole antenna **12** is provided on circuit board **11**, and both ends thereof are bent in the direction of the front side. In a power supply part around the middle of dipole antenna **12**, balun **13** is provided, which is balance-unbalance converter that prevents antenna currents from flowing onto circuit board **11** or onto case **15**. Moreover, parasitic element **14** is provided on the inner wall of case **15** in direct opposition to dipole antenna **12** on circuit board **11**. Like dipole antenna **12**, both ends of parasitic element **15** are bent in the direction of the front side of case **15**.

Given built-in antenna device **10** with the above configuration, it is possible to adjust the length and the girth of dipole antenna **12** and parasitic element **14** and the distance therebetween to predetermined levels, so as to subject the self impedance of dipole antenna **12**, the self impedance of parasitic element **14**, and the mutual impedance between dipole antenna **12** and parasitic element **14** to change. By this means, the input impedance of built-in antenna **10** can also be subjected to change so as to broaden bandwidth.

The present embodiment is thus capable of broadening bandwidth, and further miniaturization and thin modeling of a built-in antenna device, without modifying the shape of a dipole antenna element in a thick board shape or such.

Second Embodiment

One principal feature of the built-in antenna device of the second embodiment of the present invention is that both ends of a parasitic element are bent in opposite directions so as to make possible the transmission and reception of vertical polarized waves in the length direction of a case.

FIG. **2** shows a configuration of a built-in antenna device according to the second embodiment of the present invention. Parts in FIG. **2** identical to those of FIG. **1** are assigned the same numerals as in FIG. **1** without further explanations.

Built-in antenna device **20** comprises circuit board **11**, dipole antenna **12**, balun **13**, parasitic element **24**, and case **15**. Hereinafter the length direction of case **15** shall be construed such that the direction where dipole antenna **12**, balun **13**, and parasitic element **24** lie is the depth side, and the direction where dipole antenna **12**, balun **13**, and parasitic element **24** are not provided is the front side.

Parasitic element **24** is provided on the inner wall of case **15** in direct opposition to dipole antenna **12** on circuit board **11**. Like dipole antenna **12**, one end of parasitic element **24** is bent in the direction of the front side of case **15**, while the other end is bent in the depth side of case **15**, which is contrary to dipole antenna **12**.

Given built-in antenna device **20** with the above configuration, it is possible to adjust the length and the girth of dipole antenna **12** and parasitic element **24** and the distance therebetween to predetermined levels, so as to subject the self impedance of dipole antenna **12**, the self impedance of parasitic element **24**, and the mutual impedance between dipole antenna **12** and parasitic element **24** to change. By this means, the input impedance of built-in antenna **20** can also be subjected to change so as to broaden bandwidth.

Moreover, one end of parasitic element **24** is bent in the direction of the front side of case **15** like dipole antenna **12**, while the other end is bent in the depth side of case **15**, which is contrary to dipole antenna **12**, thereby making possible the transmission and reception of vertical polarized waves in the length direction of the case without creating antiphase antenna currents in the length direction of the case.

The present embodiment is thus capable of broadening bandwidth, and further miniaturization and thin modeling of a built-in antenna device, without modifying the shape of a dipole antenna element in a thick board shape or such. Moreover, the transmission/reception of vertical polarized waves in the length direction of a case is made possible.

Third Embodiment

One principal feature of the built-in antenna device of the third embodiment of the present invention is that one end of a parasitic element is bent, while the other end is kept unbent, so as to make possible the transmission and reception of vertical polarized waves in the length direction of a case.

FIG. **3** shows a configuration of a built-in antenna device according to the third embodiment of the present invention. Parts in FIG. **3** identical to those of FIG. **1** are assigned the same numerals as in FIG. **1** without further explanations.

Built-in antenna device **30** comprises circuit board **11**, dipole antenna **12**, balun **13**, parasitic element **34**, and case **15**. Hereinafter the length direction of case **15** shall be construed such that the direction where dipole antenna **12**, balun **13**, and parasitic element **34** lie is the depth side, and the direction where dipole antenna **12**, balun **13**, and parasitic element **34** are not provided is the front side.

Parasitic element **34** is provided on the inner wall of case **15** in direct opposition to dipole antenna **12** on circuit board **11**. Like dipole antenna **12**, one end of parasitic element **34** is bent in the direction of the front side of case **15**, while the other end is not bent, so that parasitic element **34** as a whole makes an L shape.

Given built-in antenna device **30** with the above configuration, it is possible to adjust the length and the girth of dipole antenna **12** and parasitic element **34** and the distance therebetween to predetermined levels, so as to subject the self impedance of dipole antenna **12**, the self impedance of parasitic element **34**, and the mutual impedance between dipole antenna **12** and parasitic element **34** to change. By this means, the input impedance of built-in antenna **30** can also be subjected to change so as to broaden bandwidth.

Moreover, one end of parasitic element **34** is bent in the direction of the front side of case **15** like dipole antenna **12**, while the other end is not bent, so that parasitic element **34** as a whole makes an L shape. By this means, the transmission/reception of vertical polarized waves in the length direction of the case is made possible without creating antiphase antenna currents in the length direction of the case.

The present embodiment is thus capable of broadening bandwidth, and further miniaturization and thin modeling of a built-in antenna device, without modifying the shape of a dipole antenna element in a thick board shape or such. Moreover, the transmission/reception of vertical polarized waves in the length direction of a case is made possible.

Fourth Embodiment

One principal feature of the built-in antenna device of the fourth embodiment of the present invention is that one end of a parasitic element is bent perpendicularly towards the plane of a circuit board, so as to make possible the transmission and reception of vertical polarized waves in the length direction and in the thickness direction of a case.

FIG. **4** shows a configuration of a built-in antenna device according to the fourth embodiment of the present invention. Parts in FIG. **4** identical to those of FIG. **1** are assigned the same numerals as in FIG. **1** without further explanations.

Built-in antenna device **40** comprises circuit board **11**, dipole antenna **12**, balun **13**, parasitic element **44**, and case **15**. Hereinafter the length direction of case **15** shall be construed such that the direction where dipole antenna **12**, balun **13**, and parasitic element **44** lie is the depth side, and the direction where dipole antenna **12**, balun **13**, and parasitic element **44** are not provided is the front side.

Parasitic element **44** is provided on the inner wall of case **15** in direct opposition to dipole antenna **12** on circuit board **11**. Like dipole antenna **12**, one end of parasitic element **44** is bent in the direction of the front side of case **15**, while the other end is bent perpendicularly towards the plane of circuit board **11**.

Given built-in antenna device **40** with the above configuration, it is possible to adjust the length and the girth of dipole antenna **12** and parasitic element **44** and the distance therebetween to predetermined levels, so as to subject the self impedance of dipole antenna **12**, the self impedance of parasitic element **44**, and the mutual impedance between dipole antenna **12** and parasitic element **44** to change. By this means, the input impedance of built-in antenna **40** can also be subjected to change so as to broaden bandwidth.

Moreover, one end of parasitic element **44** is bent in the direction of the front side of case **15** like dipole antenna **12**, while the other end is bent perpendicularly towards the plane of circuit board **11**. By this means, the transmission/reception of vertical polarized waves in the length direction and in the thickness direction of the case is made possible without creating antiphase antenna currents in the length direction and in the thickness direction of the case.

The present embodiment is thus capable of broadening bandwidth, and further miniaturization and thin modeling of a built-in antenna device, without modifying the shape of a dipole antenna element in a thick board shape or such. Moreover, the transmission/reception of vertical polarized waves in the length direction and in the thickness direction of a case is made possible.

Fifth Embodiment

One principal feature of the built-in antenna device of the fifth embodiment of the present invention is that a middle portion of a dipole antenna is bent perpendicularly towards the plane of a circuit board, so as to make possible the transmission and reception of vertical polarized waves in the thickness direction of a case.

FIG. **5** shows a configuration of a built-in antenna device according to the fifth embodiment of the present invention. Parts in FIG. **5** identical to those of FIG. **1** are assigned the same numerals as in FIG. **1** without further explanations.

Built-in antenna device **50** comprises circuit board **11**, dipole antenna **12**, balun **13**, parasitic element **54**, and case **15**. Hereinafter the length direction of case **15** shall be construed such that the direction where dipole antenna **12**, balun **13**, and parasitic element **54** lie is the depth side, and the direction where dipole antenna **12**, balun **13**, and parasitic element **54** are not provided is the front side.

Parasitic element **54** is provided on the inner wall of case **15** in direct opposition to dipole antenna **12** on circuit board **11**. Like dipole antenna **12**, both ends of parasitic element **54** are bent in the direction of the front side of case **15**. In addition, a middle portion of parasitic element **54** is bent perpendicularly towards the plane of the circuit board.

Given built-in antenna device **50** with the above configuration, it is possible to adjust the length and the girth of dipole antenna **12** and parasitic element **54** and the distance therebetween to predetermined levels, so as to subject the self impedance of dipole antenna **12**, the self impedance of parasitic element **54**, and the mutual impedance between dipole antenna **12** and parasitic element **54** to change. By this means, the input impedance of built-in antenna **50** can also be subjected to change so as to broaden bandwidth.

Moreover, both ends of parasitic element **54** are bent in the direction of the front side of case **15** like dipole antenna **12**, and, in addition, a middle portion of parasitic element **54** is bent perpendicularly towards the plane of the circuit board. By this means, the transmission/reception of vertical polarized waves in the thickness direction of the case is made possible without creating antiphase antenna currents in the thickness direction of the case.

The present embodiment is thus capable of broadening bandwidth, and further miniaturization and thin modeling of a built-in antenna device, without modifying the shape of a dipole antenna element in a thick board shape or such. Moreover, the transmission/reception of vertical polarized waves in the thickness direction of a case is made possible.

Sixth Embodiment

One principal feature of the built-in antenna device of the sixth embodiment of the present invention is that both ends of a parasitic element are bent in mutually opposite directions and that a middle portion of the parasitic element is bent perpendicularly towards the plane of a circuit board, so as to make possible the transmission and reception of vertical polarized waves in the length direction and in the thickness direction of a case.

FIG. **6** shows a configuration of a built-in antenna device according to the sixth embodiment of the present invention. Parts in FIG. **6** identical to those of FIG. **1** are assigned the same numerals as in FIG. **1** without further explanations.

Built-in antenna device **60** comprises circuit board **11**, dipole antenna **12**, balun **13**, parasitic element **64**, and case **15**. Hereinafter the length direction of case **15** shall be construed such that the direction where dipole antenna **12**, balun **13**, and parasitic element **64** lie is the depth side, and the direction where dipole antenna **12**, balun **13**, and parasitic element **64** are not provided is the front side.

Parasitic element **64** is provided on the inner wall of case **15** in direct opposition to dipole antenna **12** on circuit board **11**. Like dipole antenna **12**, one end of parasitic element **64** is bent in the direction of the front side of case **15**, while the other end is bent in the depth side of case **15**, which is contrary to dipole antenna **12**. In addition, a middle portion of parasitic element **64** is bent perpendicularly towards the plane of the circuit board.

Given built-in antenna device **60** with the above configuration, it is possible to adjust the length and the girth of dipole antenna **12** and parasitic element **64** and the distance therebetween to predetermined levels, so as to subject the self impedance of dipole antenna **12**, the self impedance of parasitic element **64**, and the mutual impedance between dipole antenna **12** and parasitic element **64** to change. By this means, the input impedance of built-in antenna **60** can also be subjected to change so as to broaden bandwidth.

Moreover, one end of parasitic element **64** is bent in the direction of the front side of case **15** like dipole antenna **12**, while the other end is bent towards the depth of case **15**, which is contrary to dipole antenna **12**, and, in addition, a middle portion of parasitic element **64** is bent perpendicularly towards the plane of the circuit board. By this means, the transmission/reception of vertical polarized waves in the length direction and in the thickness direction of the case is made possible without creating antiphase antenna currents in the length direction and in the thickness direction of the case.

The present embodiment is thus capable of broadening bandwidth, and further miniaturization and thin modeling of a built-in antenna device, without modifying the shape of a dipole antenna element in a thick board shape or such. Moreover, the transmission/reception of vertical polarized waves in the thickness direction of a case is made possible.

Seventh Embodiment

One principal feature of the built-in antenna device of the seventh embodiment of the present invention is that a parasitic element is provided with a lumped constant, so as to change the ratio of transmission/reception strength and sensitivity of every polarized wave.

FIG. **7** shows a configuration of a built-in antenna device according to the seventh embodiment of the present invention. Parts in FIG. **7** identical to those of FIG. **1** are assigned the same numerals as in FIG. **1** without further explanations.

Built-in antenna device **70** comprises circuit board **11**, dipole antenna **12**, balun **13**, parasitic element **74**, case **15**, and lumped constant **76**. Hereinafter the length direction of case **15** shall be construed such that the direction where dipole antenna **12**, balun **13**, and parasitic element **74** lie is the depth side, and the direction where dipole antenna **12**, balun **13**, and parasitic element **74** are not provided is the front side.

Parasitic element **74** is provided on the inner wall of case **15** in direct opposition to dipole antenna **12** on circuit board **11**. Like dipole antenna **12**, one end of parasitic element **74** is bent in the direction of the front side of case **15**, while the other end is not bent, so that parasitic element **74** as a whole makes an L shape. In addition, parasitic element **74** is provided with lumped constant **76**.

Given built-in antenna device **70** with the above configuration, it is possible to adjust the length and the girth of dipole antenna **12** and parasitic element **74** and the distance therebetween to predetermined levels, so as to subject the self impedance of dipole antenna **12**, the self impedance of parasitic element **74**, and the mutual impedance between dipole antenna **12** and parasitic element **74** to

change. By this means, the input impedance of built-in antenna **70** can also be subjected to change so as to broaden bandwidth.

Moreover, one end of parasitic element **74** is bent in the direction of the front side of case **15** like dipole antenna **12**, while the other end is not bent, so that parasitic element **74** as a whole makes an L shape. By this means, the transmission/reception of vertical polarized waves in the length direction of the case is made possible without creating antiphase antenna currents in the length direction of the case. In addition, parasitic element **74** is provided with lumped constant **76**. By this means, the electrical length ratio of the bent portion and the unbent portion can be changed, so that the ratio of transmission/reception strength and sensitivity between horizontal waves and vertical polarized waves can also be subjected to change.

The present embodiment is thus capable of broadening bandwidth, and further miniaturization and thin modeling of a built-in antenna device, without modifying the shape of a dipole antenna element in a thick board shape or such. Moreover, the transmission/reception of vertical polarized waves in the thickness direction of a case is made possible. In addition, providing a parasitic element with a lumped constant makes it possible to change the ratio of strength and sensitivity in varying directions where polarized waves are transmitted and received.

Eighth Embodiment

One principal feature of the built-in antenna device of the eighth embodiment of the present invention is that a parasitic element is provided with a lumped constant and disposed on a circuit board plane, for further miniaturization and thin modeling of the device.

FIG. **8** shows a configuration of a built-in antenna device according to the eighth embodiment of the present invention. Parts in FIG. **8** identical to those of FIG. **1** are assigned the same numerals as in FIG. **1** without further explanations.

Built-in antenna device **80** comprises circuit board **11**, dipole antenna **12**, balun **13**, parasitic element **84**, case **15**, and lumped constant **86**.

Parasitic element **84** is provided on circuit board **11** near dipole antenna **12**. Parasitic element **84** is provided with lumped constant **86**.

Given built-in antenna device **80** with the above configuration, it is possible to adjust the length and the girth of dipole antenna **12** and parasitic element **84** and the distance therebetween to predetermined levels, so as to subject the self impedance of dipole antenna **12**, the self impedance of parasitic element **84**, and the mutual impedance between dipole antenna **12** and parasitic element **84** to change. By this means, the input impedance of built-in antenna **80** can also be subjected to change so as to broaden bandwidth.

Since parasitic element **84** is provided with lumped constant **86**, it is possible to change the electrical length of parasitic element **84** and make the length of parasitic element **84** in the short direction of the case within the length of the short direction of circuit board **11**. By this means, the device can be made further small and thin.

The present embodiment is thus capable of broadening bandwidth, and further miniaturization and thin modeling of a built-in antenna device, without modifying the shape of a dipole antenna element in a thick board shape or such.

Ninth Embodiment

One principal feature of the built-in antenna device of the ninth embodiment of the present invention is that a reflector is provided in direct opposition to a parasitic element over a dipole antenna, so as to enhance gain and reduce SAR.

FIG. **9** shows a configuration of a built-in antenna device according to the ninth embodiment of the present invention. Parts in FIG. **9** identical to those of FIG. **1** are assigned the same numerals as in FIG. **1** without further explanations.

Built-in antenna device **90** comprises circuit board **11**, dipole antenna **12**, balun **13**, parasitic element **14**, case **15**, and reflector **96**.

Reflector **96** is positioned in direct opposition to parasitic element **14** over circuit board **11** and dipole antenna **12**. However, reflector **96**, as long as it is opposite to circuit board **11** and dipole antenna **12**, can be provided on the inner wall of case **15** or on the back of circuit board **11**.

Given built-in antenna device **90** with the above configuration, it is possible to adjust the length and the girth of dipole antenna **12** and parasitic element **14** and the distance therebetween to predetermined levels, so as to subject the self impedance of dipole antenna **12**, the self impedance of parasitic element **14**, and the mutual impedance between dipole antenna **12** and parasitic element **14** to change. By this means, the input impedance of built-in antenna **90** can also be subjected to change so as to broaden bandwidth.

Since parasitic element **14** and reflector **96** are positioned opposite to each other over circuit board **11** and dipole antenna **12**, built-in antenna device **90** acquires a directivity in the thickness direction of the case, thereby enhancing gain and reducing SAR.

The present embodiment is thus capable of broadening bandwidth, enhancing gain, and reducing SAR with additional directivity, without modifying the shape of a dipole antenna element into a thick board shape or such.

Tenth Embodiment

One principal feature of the built-in antenna device of the tenth embodiment of the present invention is that a number of reflectors are provided opposite from a parasitic element over a dipole antenna, so as to enhance gain and reduce SAR.

FIG. **10** shows a configuration of a built-in antenna device according to the tenth embodiment of the present invention. Parts in FIG. **10** identical to those of FIG. **1** are assigned the same numerals as in FIG. **1** without further explanations.

Built-in antenna device **100** comprises circuit board **11**, dipole antenna **12**, balun **13**, parasitic element **14**, case **15**, and reflectors **106***a* and **106***b*.

Reflectors **106***a* and **106***b* are provided in pair opposite to parasitic element **14** over circuit board **11** and dipole antenna **12**. However, reflectors **106***a* and **106***b*, as long as they are opposite from parasitic element **14** over circuit board **11** and dipole antenna **12**, can be provided on the inner wall of case **15** or on the back of circuit board **11**.

Given built-in antenna device **100** with the above configuration, it is possible to adjust the length and the girth of dipole antenna **12** and parasitic element **14** and the distance therebetween to predetermined levels, so as to subject the self impedance of dipole antenna **12**, the self impedance of parasitic element **14**, and the mutual impedance between dipole antenna **12** and parasitic element **14** to change. By this means, the input impedance of built-in antenna **100** can also be subjected to change so as to broaden bandwidth.

Since parasitic element **14** and reflectors **106***a* and **106***b* are positioned opposite to each other over circuit board **11** and dipole antenna **12**, built-in antenna device **100** acquires a directivity in the thickness direction of the case, which then leads to enhanced gain and reduced SAR.

The present embodiment is thus capable of broadening bandwidth, enhancing gain, and reducing SAR with additional directivity, without modifying the shape of a dipole antenna element into a thick board shape or such.

Eleventh Embodiment

One principal feature of the built-in antenna device of the eleventh embodiment of the present invention is to make a portion of a case with steel so as to enhance gain and reduce SAR.

FIG. **11** shows a configuration of a built-in antenna device according to the eleventh embodiment of the present invention. Parts in FIG. **11** identical to those of FIG. **1** are assigned the same numerals as in FIG. **1** without further explanations.

Built-in antenna device **110** comprises circuit board **11**, dipole antenna **12**, balun **13**, parasitic element **14**, steel cover **15***a*, and resinous cover **15***b*.

The case of a built-in antenna device of the present embodiment is configured such that steel cover **15***a* is the opposite side to parasitic element **14** in relation to circuit board **11** and dipole antenna **12**, and resinous cover **15***b* is the same side as parasitic element **14** in relation to circuit board **11** dipole antenna **12**.

Given built-in antenna device **110** with the above configuration, it is possible to adjust the length and the girth of dipole antenna **12** and parasitic element **14** and the distance therebetween to predetermined levels, so as to subject the self impedance of dipole antenna **12**, the self impedance of parasitic element **14**, and the mutual impedance between dipole antenna **12** and parasitic element **14** to change. By this means, the input impedance of built-in antenna **110** can also be subjected to change so as to broaden bandwidth.

Since steel cover **15***a* that is opposite to parasitic element **14** over circuit board **11** and dipole antenna **12** functions as a reflection board, built-in antenna device gains a directivity in the thickness direction of the case, thereby enhancing gain and reducing SAR.

The present embodiment is thus capable of broadening bandwidth, and further miniaturization and thin modeling of a built-in antenna device, without modifying the shape of a dipole antenna element into a thick board shape or such. Moreover, adding a directivity makes it possible to enhance gain and reduce SAR.

The above-described modes of embodiment can be combined with each other. That is, modifying the shape a parasitic element, providing a parasitic element with a lumped constant, the position of a reflector, and the use of a steel cover can be implemented in combination.

Furthermore, the above first through sixth embodiments show configurations in which the shape of a parasitic element is modified only in typical manners. However, it is still possible to modify the shape of a parasitic element in various other ways and transmit and receive polarized waves in and from the directions of interest.

As described above, the present invention is capable of broadening bandwidth and realizing further miniaturization and thin modeling without making the whole device in a flat shape.

Furthermore, the present invention makes a device smaller and thinner without making the whole device in a flat shape, and still achieves enhanced gain and reduced SAR.

The present invention is based on Japanese Patent Application No. 2001-225104 filed on Jul. 25, 2001, and Japanese Patent Application No. 2002-080569 filed on Mar. 22, 2002, entire content of which is expressly incorporated herein for reference.

Industrial Applicability

The present invention is applicable to built-in antenna devices.

What is claimed is:

1. A built-in antenna device comprising:

a radiation element of a dipole configuration that is supplied power and provided on a circuit board, both ends of said radiation element turned in a same direction;

a parasitic element for use in matching provided opposite to said radiation element, both ends of said parasitic element bent to the same direction as said both ends of said radiation element; and

a case current suppressor provided in a power supply part of said radiation element to suppress a case current.

2. The built-in antenna device according to claim **1**, wherein an unbent portion of said parasitic element has a part in a shape of a step that is perpendicular towards a plane of said circuit board.

3. The built-in antenna device according to claim **1**, wherein said parasitic element is provided with a lumped constant.

4. The built-in antenna device according to claim **1**, wherein a reflection element is provided opposite to said parasitic element over said radiation element.

5. The built-in antenna device according to claim **1**, further comprising a case, at least a portion of which that is opposite to said parasitic element over said radiation element is made of steel.

6. A built-in antenna device comprising:

a radiation element of a dipole configuration that is supplied power and provided on a circuit board, both ends of said radiation element turned in a same direction;

a parasitic element for use in matching provided opposite to said radiation element, one end of said parasitic element bent to the same direction as said both ends of said radiation element, and the other end bent to an opposite direction; and

a case current suppressor provided in a power supply part of said radiation element to suppress a case current.

7. The built-in antenna device according to claim **6**, wherein an unbent portion of said parasitic element has a part in a shape of a step that is perpendicular towards a plane of said circuit board.

8. The built-in antenna device according to claim **6**, wherein said parasitic element is provided with a lumped constant.

9. The built-in antenna device according to claim **6**, wherein a reflection element is provided opposite to said parasitic element over said radiation element.

10. The built-in antenna device according to claim **6**, further comprising a case, at least a portion of which that is opposite to said parasitic element over said radiation element is made of steel.

11. A built-in antenna device comprising:

a radiation element of a dipole configuration that is supplied power and provided on a circuit board, both ends of said radiation element turned in a same direction;

a parasitic element for use in matching provided opposite to said radiation element, only one end of said parasitic element bent to the same direction as said both ends of said radiation element; and

a case current suppressor provided in a power supply part of said radiation element to suppress a case current.

12. The built-in antenna device according to claim **11**, wherein an unbent portion of said parasitic element has a part in a shape of a step that is perpendicular towards a plane of said circuit board.

13. The built-in antenna device according to claim **11**, wherein said parasitic element is provided with a lumped constant.

14. The built-in antenna device according to claim **11**, wherein a reflection element is provided opposite to said parasitic element over said radiation element.

15. The built-in antenna device according to claim **11**, further comprising a case, at least a portion of which that is opposite to said parasitic element over said radiation element is made of steel.

16. A built-in antenna device comprising:

a radiation element of a dipole configuration that is supplied power and provided on a circuit board, both ends of said radiation element turned in a same direction;

a parasitic element for use in matching provided opposite to said radiation element, one end of said parasitic element bent to the same direction as said both ends of said radiation element, and the other end bent to a direction that is perpendicular to a plane of said circuit board; and

a case current suppressor provided in a power supply part of said radiation element to suppress a case current.

17. The built-in antenna device according to claim **16**, wherein said parasitic element is provided with a lumped constant.

18. The built-in antenna device according to claim **16**, wherein a reflection element is provided opposite to said parasitic element over said radiation element.

19. The built-in antenna device according to claim **16**, further comprising a case, at least a portion of which that is opposite to said parasitic element over said radiation element is made of steel.

20. A built-in antenna device comprising:

a radiation element of a dipole configuration that is supplied power and provided on a circuit board, both ends of said radiation element turned in a same direction;

a parasitic element for use in matching provided near said radiation element on said circuit board; and

a case current suppressor provided in a power supply part of said radiation element to suppress a case current.

21. The built-in antenna device according to claim **20**, wherein said parasitic element is provided with a lumped constant.

22. The built-in antenna device according to claim **20**, further comprising a case, at least a portion of which that is opposite to said parasitic element over said radiation element is made of steel.

23. A built-in antenna device comprising:

a radiation element of a dipole configuration that is supplied power and provided on a circuit board, both ends of said radiation element turned in a same direction;

a case, at least a portion of which that is opposite to said radiation element over said circuit board is made of steel; and

a case current suppressor provided in a power supply part of said radiation element to suppress a case current.

24. The built-in antenna device according to claim **23**, wherein said radiation element is provided with a lumped constant.

25. A built-in antenna device comprising:

a radiation element of a dipole configuration that is supplied power and provided on a circuit board, both ends of said radiation element turned in mutually opposite directions;

a case, at least a portion of which that is opposite to said radiation element over said circuit board is made of steel; and

a case current suppressor provided in a power supply part of said radiation element to suppress a case current.

26. The built-in antenna device according to claim **25**, wherein said radiation element is provided with a lumped constant.

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